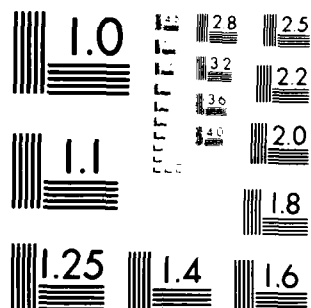


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THE PERCEPTION OF OBJECTS AND THEIR FUNCTIONAL USES

Marie Knowlton
Frank Keil
Marvin D. Glock

Technical Report No. 8

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ABSTRACT

Five common objects were selected to which multiple uses could be assigned. The eye scanning patterns of 43 subjects were examined as they made decisions regarding possible functional uses of these objects. We hypothesized that specific features of objects must be attended to before such decisions can be made. The stimuli were line drawings of the objects with specific feature areas delineated. Each object was shown in four orientations selected by rotating the object in the picture plane by 90 degree increments. Correlations were computed between the fixations in each of the feature areas and canonical and functional scales developed by independent introspective ratings. Significant correlations occurred with specific areas of familiar objects and the canonical scales. One unfamiliar object had significant correlations with the functional scales for that object. Therefore, subjects did rely on specific features to identify the objects and apparently used the features to retrieve a semantic label from which they made inferences about functional information.

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THE PERCEPTION OF OBJECTS AND THEIR FUNCTIONAL USES

1.0. The Information Available in Pictures:

Research on the perception of pictures has usually been concerned with complicated real world scenes that contain many objects (Handler and Parker, 1976; Biederman, 1972; Biederman, Glass, and Webb, 1973; Mackworth and Morandi, 1967). In analyzing these pictures it is difficult to develop a concise and complete delineation of the information available in the picture. Furthermore, it is not possible to separate the information available in the objects themselves from the information created by the interaction between objects. At present there is no means of delineating the categories of information available from individual objects. Recently, Bieger (1982) has proposed a taxonomy of information available in picture/text procedural instructions. Further investigations by Bieger and Glock (1982) have explored the effect on comprehension of putting different categories of information in either pictures, text, or both. In the investigations presented in this report we will continue the exploration of the information available in pictures. Specifically two categories of information will be investigated. These are the categories of canonical information and functional information. Canonical information is closely related to the category of inventory information of Bieger. It is concerned with the identity of the object or objects presented in the picture. The canonical orientation of an object is the orientation in which the object is most readily recognized, or the orientation which is most typical of that object. Functional information is information concerning how an object functions or how it can be used. As such, it is a composite of information from three other categories of Bieger. These are the categories of descriptive

information which specifies the figurative details of an object; spatial information, which includes information concerning the orientation of an object (but only as it relates to the function and not the identity of the object); and contextual information, which provides the theme or the context in which the object is to operate.

The studies reported here are an examination of the interrelationship between canonical and functional information. Pilot studies suggested that subjects might first determine the identity of objects portrayed in pictures and from the information available from the identity determine the function of the object. To test this further, eye movements were monitored as subjects made decisions as to possible functional uses of common objects. The location and duration of fixations on the object were analyzed and correlated with canonical and functional scales that were developed independently.

2.0. METHODS

2.1. Selection of Objects: Five objects were selected to which multiple uses could be assigned. This set of objects consisted of a flower pot, a mitten, a paring knife, a wooden wedge, and a cup. It was assumed that these were common objects and that subjects would have schema that related to them and their normal functions. This was not the case for all objects in the set. The wedge was an ambiguous object for many subjects. It became apparent in later studies that subjects did not have a name or identity for this object. This ambiguity had important consequences in later studies.

2.2 Selection of Functions: Ten subjects, who were students in an introductory psychology class and who received course credit for their participation, were interviewed individually. They were presented with each of

these objects and asked to state as many uses, or functions, as they could for this object. They were not given a time limit but were monitored by the examiner. When their responses became unproductive they were presented with another object from the set. Lists of functions for each object were then compiled and the orientation necessary for each of the functions was recorded. Three functions for each object were then selected. Each function necessitated that the object be in a different orientation. One orientation of each object was assigned the "normal" or 0 degree orientation (Figure 1). These were arbitrarily chosen to correspond to what was thought by the examiner to be the most commonly seen perspective of the object. One function each for a 0, 90, and 180 degree rotation from this orientation was selected for each object. These functions are presented in Table 1.

Insert Table 1 about here

These objects have normal or "common uses. Three pilot studies indicated that mixing common and unusual functions in the same experiment led to confusion and erratic responses. If common uses were included along with the unusual uses, subjects frequently took much longer to respond. They later reported that they were primed for the unusual functions and, in the instances of common functions, had difficulty in changing their response set. Therefore, the common uses were avoided in an effort to make all functions more uniform in kind, i.e. the cup was not assigned the function of holding beverages, and the knife was not assigned the function of cutting or slicing. These selected functions are not equivalent in their unusualness of function. However, 11 new subjects indicated high agreement that one function for each object was considered functionally

poor in comparison to the other two functions. The "poor" function was given the rank of 3 by 9 out of 11 subjects, indicating this was the least typical function for that object. These functions were the flower pot as a wheel for a toy car, the mitten as a bed for a mouse, the knife to spindle bills, the wedge to spread jelly, and the cup as a cricket trap. The rating of the other two functions for each object were nearly equal in rank.

2.3. Development of Canonical and Functional Scales:

2.3.1. The canonical scales: A line drawing was made of each of the five objects. The perspective for the drawing was with the object at eye level and with the object perpendicular to the line of sight. An exception to this was the wedge. The wedge was rotated 30 degrees on the vertical axis so that it would be easily distinguished from a simple planar figure.

The position described for each object (see above) will be assigned the 0 degree orientation. The line drawings for each object were then rotated clockwise in 45 degree increments creating a series of eight drawings of each object. The eight separate drawings of each object were randomly ordered and drawn on a single page to serve as the stimuli for introspective ratings.

Twenty-five students in an introductory psychology course at Broome Community College, Binghamton, New York agreed to participate in this study. The subjects ranged in age from 18 to 45. There were 12 males and 13 females.

Each subject was presented with a booklet of five pages; each page containing one of the randomly ordered sets of eight orientations for one of the objects. They were asked to rate each picture on a scale of 1 to 7 for how typical it was to see that object in that position. A rating of 1 was considered the highest rating, or most typical orientation, and a 7 was a low rating. Each orientation was to be rated separately and one rating could be

used more than once. They were requested to score the drawings in whole numbers but some subjects did resort to decimal fractions. This did not alter the methods for analyzing the data, so these responses were included in the analysis. Means of the ratings were computed for each position of these objects (Tables 2-6).

Insert Tables 2-6 About Here

The scales were named the canonical scales. They will be used as an introspective measurement of typicality for that object (Figure 2).

Insert Figure 2 About Here

The perspective of the flower pot was the only symmetrical drawing in this study. Some interesting results are noted when comparing mirror images for the flower pot. It was expected that the mirror images would have similar ratings. Occasionally they deviate from each other. For example, the canonical rating of the 45 and 315 degree orientations are not only fairly widely separated, but the 225 degree orientation is inserted between them. None of the other objects are symmetrical in the view shown. In pairs of orientations that seem to be related there is a consistent relationship between these orientations on all scales for this object. For example, in examining the 90 and 270 degree orientations for the cup, the 270 degree orientation receives the higher rating on all scales. For other pairs of orientations this is not the case. The 90 and 270 degree

orientations for the wedge create a perspective change. The 90 degree orientation is presented as if viewed from above and the 270 degree orientation is presented as if viewed from below. These orientations maintain the same sequence on all scales. Similarly, the 45 and 315 degree orientations for the wedge also create perspective changes with the 45 degree orientation being given a slightly lower rating.

2.3.2. The Functional Scales: Functional scales for each of the 15 functions selected in section 2.2 were then developed in a manner similar to that stated in section 2.3.1. for the canonical scales. The same subjects were used and all had first participated in the canonical study. In this study the same stimuli were used except that the subjects had to rate each orientation for each proposed function. The set of randomly ordered orientations of each object was presented three times to each subject, once for each function. The task was to rate the drawings on a scale of 1 to 7 for how well that object could perform the function in that position. As in the previous study mean ratings were computed for each orientation of each object for each function (Table 1). In this manner three scales of functional goodness were developed for each object (Figures 3-7).

Insert Figures 3-7 About Here

A few comments on these functional scales seem to be in order. In two instances the orientation receiving the highest rating was not the prime orientation anticipated. In the function of the mitten as a holder for marbles the 90 degree orientation received the prime rating. However, the anticipated 180 degree orientation is not significantly different ($t=.772$, $p<.685$). The

ratings for the function of the wedge to spread jelly (Figure 6) are difficult to explain in any consistent manner. The 0 degree orientation was anticipated as the prime orientation with the 45 and 315 degree orientations anticipated as possible contenders for the prime orientation. The 270 and 90 degree orientations are inserted before the 0 degree orientation. The 0 degree and the 45 degree orientations are the only pairs that are significantly different in their ratings ($p < .002$). It is difficult to imagine how the wedge could be used to spread jelly in the 90 degree or 270 degree orientations. It is suspected that these ratings are a result of the subjects unfamiliarity with the wedge. Subjects frequently asked for the name of this object or asked what it was used for. A decision was made not to exclude it from further studies on grounds that it might provide an interesting variation due to its uniqueness as an object.

In the canonical and functional scales that were developed not every orientation is significantly different in its rating from all other ratings for that object. Nor are these a complete set of all the possible orientations for any one object. They must be considered a subset of the possible views of an object and that these views are on a continuum of possible canonical and functional goodness.

2.4. The Apparatus: The equipment for this study is the same as that reported by Hirschfeld and Bieger (1981). It consists of a Gulf and Western eye-trac camera (Model 106) which samples eye position by means of corneal reflection. It is assumed that the subject's eyes are moving with the lines of sight parallel to each other. The right eye is monitored for horizontal position and the left eye is monitored for vertical position. These two pieces of data form the coordinates for a point of fixation. The position of the eye is sampled sixty times a second in this manner. (The interval of 1/60 of a second is called a tick.) The eye trac camera is interfaced to a PDP11/03 computer by means of an A/D converter. The corneal reflections are monitored by

the eye trac camera and converted to an electrical signal which is sent to the computer and stored on a floppy disk in digital values.

The data files are then used to recreate the pattern of eye movements superimposed on an image of the stimulus by plotting them out on a Hewlett Packard 7221B plotter. After the eye movement pattern is adjusted to the frame of the stimulus, a computer program is run assigning each separate fixation to a specific area of the stimulus. In this manner the data is quantified in a form that can be analyzed statistically.

2.5. The Stimuli: The stimuli for this study consisted of line drawings of the five objects. These drawings were initially created by free-hand methods. The free-hand drawing was then digitized on the plotter using the MAPS program (Hirschfeld and Bieger, 1980). This program creates the file that stores the data for drawing the stimulus as well as designating distinct areas to which eye fixations will be assigned. The line drawings that the subject saw were drawn by the plotter with the limits set to a 3 inch by 3 inch size. This is the maximum sized square that can be drawn on the reading screen of the eye trac camera. The final drawing of an object was approximately one-half the normal size of the real object. Figure 8 shows the stimuli under two conditions. The first column is the stimuli as it is divided into its feature areas. Independent introspective judgments of three people were used to determine the limits of the feature areas assigned to each object. The second column is the stimulus as the subject saw it. A statement of a possible functional use is inserted between the brackets at the top of the page.

A computer program, ROTATE, further modified the data from the MAP program by rotating the line drawing with its feature areas 90, 180, and 270 degrees in a clockwise direction leaving the other areas of the card unmodified. In this manner stimuli depicting four different orientations of the object can be created.

All the stimuli for the four different orientations of the five target objects were drawn on the plotter. Four confusor items were also rotated and drawn using the same programs. The total set of stimuli for this study consisted of:

5 (objects) x 3 (functions) x 4 (orientations)

4 (confusors) x 3 (functions) x 4 (orientations)

The complete set of 108 items was divided into four blocks of 27 cards each. Each block contained one card for each of the 15 function statements plus 12 cards of the confusor items. Each target object was presented three times within each block of cards; once for each of the three functional use statements for that object. However, any specific orientation of a target object was presented only once within a block of slides. Each subject was assigned to one of the four blocks of slides in a predetermined manner.

It should be mentioned that in the digitization of the line drawings one object was inadvertently drawn in its mirror image. This item was the cup. The handle of the cup in this study is on the left side when the cup is in its 0 degree orientation. In the development of the canonical and functional rating scales the handle was on the right side in the 0 degree orientation. This error was not noticed until later in the study after the data were collected. It is not known how this affects the results of the experiment. It will be considered in the discussion of the results.

2.6. The Subjects: The subjects for this study were 25 undergraduate students at Cornell University, Ithaca, NY. They ranged in age from 19 to 26 years. Each received partial course credit for their participation. The data from 2 of the subjects had to be discarded because the initial adjustment in the eye trace camera was faulty. Both these subjects wore heavy glasses and this made the adjustment difficult. Five other subjects wore contact lenses but no problems were encountered in their initial adjustment.

3.0. Procedure:

The subjects were told on arrival at the reading research laboratory that they would be participating in an experiment that monitored eye movements. They were shown the apparatus and instruction was given regarding the procedure for collecting the data. It was explained that it was easier to adjust and monitor the experiment in a darkened room with only the illumination from the eye trac camera and that it was necessary for the eyes of the examiner to dark adapt before continuing with the experiment. At this point the room illumination was turned off and the further instructions were given in a semi-darkened room. The subjects were told that the technique required that the head be held immobile in the eye trac camera for the accurate monitoring of eye movements. Since immobility could make the task tiring, the whole experiment would be broken up into three segments. The subject would be taken out of the eye trac apparatus for a brief rest twice during the experiment. Even with this precaution against excessively tiring the subject, approximately one-third of the data for any one subject was lost due to head movement during a test item (23 trials out of a total of 69).

After these general instructions were given, a sample stimulus card with a screening card was presented to the subject. The picture on the stimulus card was not of any target item. The subject was told that s/he should look at a small star in the upper right corner of the screening card until this screen was removed by the examiner. On the removal of the screen s/he was to read the label stating a functional use of the object. S/he was then to look at the object in the middle of the card and make a decision as to whether the object and the label matched in function. More specifically, the decision was not "was the object a cookie cutter" but rather, "could this be used as a cookie cutter." When a decision had been reached the subject was to fixate on either the "yes"

or "no" response corner at the bottom of the card. The examiner could tell that the subject had completed the task when the subject fixated on a lower corner of the card. The subject was then instructed to look at three specific points on the card; the label, the "yes", and the "no". The fixations on these areas were held for approximately two to three seconds. These lengthy fixations on specific areas were easily identifiable in the plotted data and were used as points of adjustment in order to superimpose the eye movements more accurately on the plotter drawn stimulus. The adjustment was also important in order to check for head movement during a trial. If the final three points of fixation and the initial point of fixation on the label did not coincide, it was interpreted as a head movement during the collection of the data.

4.0. Results:

The adjusted data was run through the MATCH program (Hirschfeld and Bieger, 1980), and fixations were assigned to specific areas of the stimulus. In quantifying these fixations any fixation of six ticks (approximately 100 msec) or less was discarded. Research on eye movements indicates that little information is acquired during a saccade (Volkmann et al, 1976). In this study any fixation of less than six ticks is considered to be part of a saccade or influenced by saccadic suppression. It is assumed that during these short periods no additional information was acquired. This gives an extremely conservative estimate of the fixation time during which information is acquired.

In assigning tick fixations to specific areas, a fixation would often occur in a location causing an apparent vacillation between two adjacent areas. In these instances the fixations for the two areas were added. The total length of the fixation was then divided equally between the two areas.

The mean fixation time, in ticks, for each feature area of the objects were computed across all functions. These statistics are reported in Table 7.

Insert Table 7 About Here

The mean length of fixations for the various features vary according to the feature. Of note is the fact that some features seem to receive few fixations. For example, the cuff of the mitten and the tip of the knife blade receive approximately 20 percent of the total number of ticks for these objects. On the other hand, areas such as the thumb of the mitten and the handle of the cup receive approximately 40 per cent of the total fixations.

Since the within subject variance is too great to perform an ANOVA with these data ($F_{max}=60.9$) correlations were calculated between the fixations on the feature areas and the functional and canonical scales that were reported in section 2.3. In reporting these correlations it should be remembered that a low numerical rating on either the canonical or functional scale indicates that position is either the more typical orientation of the object, or that position is more appropriate for the proposed function. Therefore, a high positive correlation between a feature area and the canonical scale would indicate that as the object became positioned so that it was less typically oriented the feature area being examined received more fixations.

Each object was seen three times by a subject. A different functional use statement and a different orientation was presented on successive trials. A significant negative correlation was obtained between the total fixations on three of the objects and trial. These objects were the flower pot ($r=-.282$, $p<.029$), the knife ($r=-.246$, $p<.050$), and the cup ($r=-.333$, $p<.013$). For each of these three objects a partial correlation between each feature area and the canonical and functional scales was computed, controlling for trial. No partial correlations were computed for the other two objects.

A total of 10 positive correlations were obtained between feature areas of objects and the appropriate canonical scale. Five of these were positive correlations and five were negative. An additional 6 correlations were obtained between a feature area and the appropriate functional scale. Three of these were positive and three were negative (Tables 8.1-12.3).

Insert Tables 8.1-12.3 about here

The two objects that obtained no correlations between feature areas and the canonical scale (the mitten and the wedge) were also the ones that obtained no negative correlation with trial. Both of these objects had significant correlations between feature areas and the functional scales.

Since the within subject variance is too great to perform an ANOVA with these data ($F_{max}=60.9$) correlations were calculated between the fixations on the feature areas and the functional and canonical scales that were reported in section 2.3. In reporting these correlations it should be remembered that a low numerical rating on either the canonical or functional scale indicates that position is either the more typical orientation of the object, or that position is more appropriate for the proposed function. Therefore, a high positive correlation between a feature area and the canonical scale would indicate that as the object became positioned so that it was less typically oriented the feature area being examined received more fixations.

Each object was seen three times in random order. A different task statement and a different orientation was presented on successive trials. A significant negative correlation was obtained between the total fixations on three of the objects and trial number. These objects were the flower pot

($r = -.282$, $p < .029$), the knife ($r = -.246$, $p < .050$), and the cup ($r = -.333$, $p < .013$). For each of these three objects a partial correlation between each feature area and the canonical and functional scales was computed, controlling for trial. No partial correlations were computed for the other two objects.

5.0. Discussion

In the analysis of eye movements it is assumed that the mind is attending to the area that is being fixated. It could be argued that this may not necessarily be the case. The subject could be introspecting on one area while the eyes are fixated on another, or taking in information from peripheral vision. There is indirect evidence for the acquisition of information by use of peripheral vision. The eye movements of four subjects indicated no fixation on any area of the object in a total of 20 trials. Nine of these cases were from one subject. This subject's eye movement patterns could be traced from the beginning fixation on the star on the screening card, across the function label as the label was read. From the end of the function label there is a rapid sweep to the "yes" response box with no apparent pauses in the eye movement. This sweep takes less than three ticks (approximately 360 msec). Subjects that exhibit eye patterns like these must be obtaining information about the identity or function of the object in order to respond positively to the task, yet it is not apparent how they do this from the eye movement data acquired in this study.

The significant correlation of three of the objects with trial is interesting in that it indicates that in very early presentations a learning effect is present with some objects. There is an indication that as these objects are seen over successive trials, even though they are seen in different orientations and different functional uses are required of them, subjects still can respond with significantly less time spent in looking at the object. Two

objects, the mitten and the wedge, did not obtain a significant correlation for the trial effect and will be considered later.

The correlations of the fixations on some specific feature area are significant with either the canonical scale or the functional scale. Those objects in which the correlation of some feature is with the canonical scale are objects that are well known by most subjects. These objects were the flower pot, the knife, and the cup. For these objects it appears that subjects fixate on features that provide information to identify the object. These features may not be necessary for fulfilling any of the functions of the object. For example, the handle of the cup or the handle of the knife are not the features that permit the object to perform the functional capacity that is being queried. To further support this argument, notice that the features that are necessary for the function are sometimes negatively correlated with the canonical scale. The tip of the knife correlates negatively with the canonical scale yet it is required for the functions of scraping, and spindling. Significant negative correlations with the canonical scale also occur for the rim of the flower pot in the function of a wheel for a toy car, and for the base of the cup in the function of a trap for a cricket. The interpretation of these correlations is that as the object becomes less canonical in its orientation these features are given less attention. Since the task is to determine functional uses of objects the question of how these decisions are made must be answered by some reasoning other than that of looking for the features in the object that are necessary for the function. It is proposed that these decisions are made by accessing the identity of the object presented. Once the object is identified the decision can be made as to whether it has the necessary attributes to perform the function.

For the knife function of scraping paint, there is a significant positive correlation between the handle and both the functional and canonical scales and

16

a significant negative correlation between the tip and both the canonical and functional scales. This is explainable when it is realized that these two scales are significantly correlated with each other.

Similarly, in examining the cup in the function of holding vinegar there is a significant positive correlation between the base and both the canonical and functional scales. However, the correlation with the canonical scale is of greater magnitude ($p < .006$) than the correlation with the functional scale ($p < .027$).

For the two objects that have correlations only with the functional scales there is not a simple explanation. As a target object the wedge presented problems. It was mentioned that its canonical scale presented perspective shifts as it was rotated on the line of sight. In addition, the subjects were generally unfamiliar with this object, could not address it by name and generally could not state what it was used for. The wedge was an object without an identity. Without this identity subjects are willing to assign the orientations of this object a wide range of ratings (Table 5) but do not use this scale in the accessing of information concerning this object. Instead, they are more likely to directly access the functional scale.

The mitten is not lacking in familiarity. It does, however lack a canonical scale. In the initial introspective ratings the canonical scale for the mitten was very short. No position differed greatly from any other position. When the orientations of the mitten were limited to the four for this study the total length of the canonical scale was reduced even more. The 90 degree orientation and the 270 degree orientation (the extremes of this new scale) are only .68 points apart. Furthermore, t-tests show no significant differences between the ratings of any of these orientations. If the mitten does not have a canonical scale, correlations, if any, would have to be with the functional scale.

In summary, subjects, when asked to make decisions as to functional uses of objects, will first attempt to determine the identity of the object. After the object is identified the function can be accessed as though it is part of the object's identity. However, if the object does not have a canonical name, as in the case of the mitten, or if it is an unfamiliar object without a name, as in the case of the wedge, the subject addresses the functional attributes of the object. Furthermore, recall that the learning effect occurred with only three of the objects. They were the same objects that demonstrated significant correlations between specific features and the canonical names when trial is partialled out. Thus, it appears that the faster performance across trials is attributable to the learning of specific features that identify the object rather than features that fulfill the function. This seems contradictory to the evidence of other investigators (Reed and Johansen 1975; Rock et al., 1971) that subjects when presented with two dimensional forms had no memory for specific details of them when given a probed recall. If the details were presented in isolation recall was significantly better. No attempt was made to give these figures names or assign more than two dimensionality to them. The forms used by Rock were geometric, planar figures and had no semantic label or identity. The task also differed from the study presented here in that memory for the two dimensional form was required. Here, the subjects had to determine functional uses. They assumed a three dimensional form and specific attributes of that form that might not be demonstrated by the picture per se. For example, in the function of the cup for holding vinegar they assume the substance that it is made out of is impermeable to liquids and that it has a cavity within its walls. Neither of these are facts that are directly evident from the graphic illustration.

The identity of an object is the focus of this investigation. How an identity is determined, and how labels are then attached to known identities

(naming), has been the concern of many investigators studying semantic representation (Smith et al, 1974; Rosch and Mervis, 1975; Rosch et al, 1976). These studies indicate that the naming of objects is a more powerful phenomenon than merely the ability to retrieve an object or class of objects from memory. It appears that the semantic identity is also the means of addressing uncommon or unknown functions of known objects.

6.0. Implications:

Using the data from these investigations a model is proposed that presents the steps necessary in the determining of functional uses of objects. This model will serve as a focus for further research on the relationship between functional and canonical information of objects and how this information is used in decision making.

In addition to the processing model this section will also address three areas of theoretical importance. These include

- (1) theories of object perception compatible with the data
- (2) semantic implications of the research as it relates to the identification of objects, and
- (3) cognitive processes related to the task of function determination of objects.

Applications of the data in relation to the use of pictures in text for optimal comprehension will also be discussed. Finally, as this is a study that has addressed a relatively new area of cognitive research, some of the possible ways of pursuing these suggested studies will be presented.

6.1. A Model for Determining Functional Uses of Objects:

A model for the decision making process concerning functional uses of common objects is presented in Figure 9.

Insert Figure 9 About here

In this model it is assumed that the functional use is available to the individual before the object to fulfill this function is seen. In these investigations the functional use was presented in written form. The information concerning the object is presented in the form of a picture. In Step 1 of the model, the individual becomes aware of the needed function. This leads to Step 2 where the individual scans the picture for necessary information. The information that is extracted from the picture determines the identity of the object, Step 3. From the identity of the object there is direct access to additional information about the object. This could be in the form of feature lists, schema dealing with past experience with the object, categorical membership for the object, etc. The identity of the object leads to Step 4, verifying that the object can be used for the proposed function.

Between the identity of the object and the additional information there is a partial barrier. This barrier permits processing in the left to right direction, that is, from the object identity to the additional information. Processing from right to left, however, is partially inhibited. It may be that there are more necessary steps in this pathway that are not, as yet, identified. These could be steps where the featural components and categorical membership, etc. are combined into an identity. If that is the case the pathway between the identity and the additional information is very different depending on the processing direction.

Now consider the case where there is no identity for the object. Without an identity for the object step 4 must be reached by a different pathway. It is proposed that this is accomplished by separately addressing the additional information that is so readily accessible from, or a part of the identity of the

object. To proceed with this task when step 3 is missing takes longer time than when it is present. This can be thought of as the addition of a step, that of establishing an identity for an object. However, since the identity of an object develops from an individual's interaction with the object it also includes the elimination of other steps. These would be steps that search for specific features considered necessary for the function. This is an issue to test in later investigations. Evidence for a shift in the features of an object attended to as the individual develops an identity for the object could be interpreted as the elimination of steps since those features are no longer being searched for. It also would support the addition of a step since new features are attended to.

6.2. Theories of Object Perception:

The study of eye movements has been helpful in the interpretation of the data from the reaction time studies on the perception of functions of objects. Much of the careful, detailed research on eye movements is concerned with the reading process. The patterns of eye movements in the perception of pictures are very different and this needs to be kept in mind when such methods are used in studying cognition. The reading process is governed by constraints relating to the direction of the eye movements. In English, text is printed in lines from left to right and from the top to the bottom of the page. There is no such constraint on the perception, or "reading", of a picture. The eye can start in any location on the page and scan in any sequence. Art styles have developed in which a sequence is imposed on the scene. The viewer is taken on a journey through a landscape by a set of conventions that direct the gaze through the scene in an intentional sequence. This, however, is not the kind of picture that this study addresses. Here, the concern is with the illustration of objects to make them as lifelike as possible but to present them without a background or context. The context is supplied by the function that is

proposed. In so presenting the objects it is argued that no directionality of scanning is imposed on the subject other than one of habit due to the influence of reading patterns, which may be considerable. All the subjects in these studies were college students and as such they have had much experience with text reading; their eye movement patterns may be influenced by this well developed skill.

In addition to the sequence of fixations required in text reading, the perception of pictures may also differ in the size of the perceptual window. The dimensions of the fixated area from which information can be acquired have been investigated with great precision for the reading of text (Rayner, 1975, McConkie, 1976) but a task involving picture perception requires different strategies. The subject is not confined to a linear forward or regressive movement when determining the next fixation. The task, therefore, is more one of scanning rather than reading. This eye tracking study suggests that the window size for some subjects may include most of the area of the stimulus card. These were the subjects that did not appear to fixate on any area of the picture but immediately proceeded to a response box fixation after reading the function label. An alternate explanation is that the subject is able to voluntarily change the size of the perceptual window with the demands of the task. A picture scanning task may require a larger window than reading does. If the area that is fixated is the area to which attention is directed, then it is necessary to know how large the window of attention is in order to determine the extent of the area from which information could be acquired during any one fixation.

A third important way in which picture scanning differs from the reading process concerns the expectations that are set up during the task. Reading involves processing the written form of some known language. Since it is

language, it has a specific form or syntax. The syntax places certain expectancies or constraints on the text that follows. In scanning a picture there is no necessary sequential input. That is not to say that there is no syntax to picture perception, but, rather, if a picture syntax can be formulated it would not necessarily be similar or comparable to the syntax of a language. It would appear that expectancies are set up when scanning a picture (Hackworth and Morand, 1957) but these expectancies are more constrained by context within the picture than by any sequential syntactic structure relating to featural representations of the picture. Noton and Stark (1971) have proposed a multistage theory of picture recognition. They posit that memory traces of features are matched serially with the object. These features are the parts of the object that yield the most information, such as angles, curves, etc. The memory traces are assembled in an internal representation called a feature ring. This feature ring is formed from the scan path the eye takes as attention is shifted from feature to feature in a preferred order. There was no evidence for verification of this theory in the studies reported here. It may be that the pictures used in this study were not complex enough to demonstrate a feature cycle. Also, varying the orientation of the object required the subject to search for identifying features in different areas of the picture. This was not a concern of the Noton and Stark study, which was a recognition task of previously seen pictures. Also decomposition into such features may be an over simplification.

Previous research on eye movements in picture perception contains much agreement that pictures have areas of differing informativeness (Salapatek and Kessen, 1966; Rock, Halper and Clayton, 1972; Zusne and Michels, 1964). Some of these studies have noted areas of greater pattern density, intersection of lines, and closed space as being high in information content. Such areas were fixated more frequently and for longer durations than other areas. However,

these studies were often done with artificial shapes, such as planar geometric figures. As such, these forms did not have a three dimensional identity, as an object from the environment. Conversely, when reducing a three dimensional object to a two dimensional representation the additional information concerning its identity is still present in the picture. It is, therefore, necessary to be very careful when evaluating the use of these studies for the present purpose. For example, in the studies reported here, the hand region of the mitten is mostly empty space and could be considered to be low in informational content. It could be argued that one would expect fewer fixations in this area. Indeed, this is the case. However, the cuff of the mitten is high in pattern density. From these earlier studies one would expect that this area would be fixated frequently. This is not the case. The thumb, furthermore, is an area of open space that receives more attention than would be expected. Clearly, a comprehensive theory of picture perception must be concerned with natural objects or their representations as well as with randomly generated shapes. The information available in these two classes of graphics is very different and the manner in which one class is treated may not provide the viewer with the necessary information for adequately comprehending the other.

6.3. Semantic Implications of the Reported Studies:

Subjects in this study first identified the object that was presented and then decided if it could fulfill the proposed function. Since the correlations for the known objects were with the canonical scale and not the functional scale, the required information is apparently more easily retrieved through the identity of the object rather than through the features of the object that are most relevant for the function. Apparently not all features are of equal importance in making decisions as to the functional uses of an object. Thus, one could interpret this as support for the Smith, Shoben and Rips (1974) theory of semantic representation of objects classifying the features of objects as

defining or characteristic features, depending on whether they are required, or optional for identification. Alternatively, consider the task as one of determining family membership (Rosen and Mervis, 1972). Each of the known items (pot, mitten, knife, cup) shares characteristics in common with all members of the family of objects to which it belongs. As the object deviates from its most characteristic orientation the task entails checking more thoroughly for family resemblance. When the prototype and the object are sufficiently similar the object can be included in the category. In the case of the studies presented here, it may be that the objects portrayed are sufficiently simple so that they require the checking of only a few features to distinguish them from non-family members. Either theory could be used to interpret the results. They do not seem to differ greatly from each other. It has been shown in these studies that subjects do seem to use specific features in determining the identity of objects, but all features of an object are not of equal importance in this determination.

6.4. Cognitive Processes in the Determination of Functional Use Objects:

The task proposed in this study could be considered to be one of determining membership in functional use categories. When a subject is asked if the object portrayed could be used to fulfill a specific function, it can be thought of as a decision process to determine if the object contains the defining features for inclusion in the family of objects that fulfill that function. Assume, for example, that a feature similar to the tip of the knife is a defining feature for all objects in the family of objects that can be used to spindle bills. In this case, it would be expected that subjects would fixate on the tip of the knife in order to verify inclusion in that category. Varying the proposed function could require other features to become the defining features for the determination of class membership. There is no evidence that

is the case. Instead, the results suggest that the features that are fixated are those that are associated with the identity of the object, or characteristic features. To continue with the example of the knife, subjects fixate on the handle of the knife as a characteristic feature. This feature is not correlated with the functional scale but, rather, the canonical scale. Not only is it significantly correlated with the canonical scale for the function of spinning bills, but for the function of scraping paint as well.

The wedge, which was a relatively unknown object displays some interesting results. Here, (Table 11.1-11.3) not only are the significant relationships with the functional scale, but if the nearly significant correlations are considered, (those of $p < .06$) it can be observed that they, also, vary with the functional scale. It would be interesting to test this in a more constrained experiment by varying the functions of unknown objects. In this way we could determine if there are different defining features for these objects dependent on the different functional classes for which they are intended.

In any case, the task as it was proposed in this study, appears to be a multistage one. The subject when first presented with the requirement to determine a possible functional use will attempt to determine the identity of an object. Through its identity, the additional information of possible functions is accessed. If the object has no identity, i.e. if it is an unknown object, subjects then search for the features necessary for the proposed function. The two stage process of first identifying the object and then the function seems to be an easier and faster process than the one stage process of addressing only the features (Table 7). The total length of fixation times for all known objects are less than those for the wedge. It is even more striking when one is aware that the total fixation length for the cup is inflated by one function, that of the cricket trap, which was considered a highly unusual function. The total length of fixations for this function was 65.4 ticks. For the functions of holding vinegar and scooping sand the total fixation lengths were 34.7 and 35.7

tions, respectively.

In considering the task, then, to be either a one or two stage task some further considerations are in order. If the determination of the function of an object is either the second stage of a two stage task or the only stage of a one stage task there is indirect evidence that these are very different processes. Since the different lengths of total fixations on the object are necessary before the subject responds positively to the function queried. If these are different processes it remains to be determined how they differ. The task presented here was focused on the functions of objects. The subjects set aside this task to first determine the identity of the objects. From the identity of the objects there is access to some lexical or encyclopedic knowledge, or a schema, for the functions proposed. In absence of an identity for an object the subjects perform a feature search to determine if the object belongs to the class of objects that fulfill the function. This feature search is a more time consuming operation than that for a known object and may be of more than one step. It appears that some of the time is spent in attempting to identify the object before resorting to the feature search or that each comparison in a serial feature search requires the task to take more time.

6.5. Application of the Findings of these Studies:

The findings of these studies have direct application to the many instances in which illustrations of known and unknown objects are used to enhance meaning and increase comprehension. They are also applicable to areas of learning and concept development. These issues will now be examined in an attempt to address the more practical side of these studies.

6.5.1. The Illustration of Objects. In textbooks, procedural manuals, instructions, and the many other places in which pictures of objects are used to convey information it must first be decided what objects to portray.

No attempt will be made to propose guide lines for this process since this was not a concern of this study. Current research in information content of picture/text materials (Bieger, 1962) may lead to more specific identification of the situations in which the information presented in pictorial form will be more useful to the reader.

After the decision has been made as to which objects are to be illustrated, the second decision must be to decide how to portray these objects. This study suggests that for maximum comprehension with the least difficulty these objects should be portrayed in their canonical orientations. The functional use position may be different from this orientation but it is the canonical orientation that should be portrayed. This is especially significant in cases where a familiar object is being portrayed and in the first instances when the object is encountered by the reader.

No instruction will be given for determining canonical orientation of objects. This is another field that could profit from further research. It is apparent that specific features of the objects are highly correlated with the canonical orientation. These salient features should be given prominence in the illustration of the object or even emphasized as in cartoons. Familiar objects have a significant correlation for the total time spent fixating on the object (and on fixating specific features of the object) with the presentation trial. Soon after the initial presentation it seems that the representation of the object is fixed in memory and varying the orientation of the object does not markedly influence the subsequent task. It must be remembered that in these studies the features of the objects were held constant. All illustrations of an object had the same number and expression of the features presented. Only the orientation and the function of the object were varied. If the orientation of the object is varied in a manner that conceals some feature or reveals a hidden one it may affect the comprehension of the material. This has not been tested.

Thirdly, it is important to know which objects are known objects and which

are unknown, or unfamiliar objects to the reader. For the illustration of unknown objects there are some additional constraints. Only one object, the wedge, was considered unknown in this study and as such it is questionable whether it is possible to generalize from a set containing one member. However, there appear to be some real differences in the manner in which the subjects addressed this object as opposed to the other known objects. Subjects were quite willing to give it a canonical orientation. This orientation may not have been based on the same parameters that were used for the known objects since the object was unknown and its functions and normal use position could only be assumed. Instead, subjects may have oriented it according to gravitational stability and/or to usual perspectives for objects with weight and solidity. It is also possible that canonical orientation was assigned according to some subject-proposed function unknown to the examiner. It would be desirable to know how canonical orientations are acquired for unknown objects and if such an identity can be assigned to an unknown object for instructional purposes.

6.5.2. Functional Fixedness and Canonical Orientation: The results of this research contribute to the development of a theoretical base encompassing the phenomenon of functional fixedness. From such a base, future research could then ensue in order to further the understanding and to develop programs to counter-act the limitations of functional fixedness. The differences that subjects show in their scanning patterns for known and unknown objects indicate that when presented with a task that requires the determination of unusual functions the functional features of the object are attended to more closely when the object is unknown. When the object is a known object the canonical features are addressed and from the identity of the object the encyclopedic knowledge is accessed. Functional fixedness can be thought of as a situation in which no encyclopedic reference occurs under the entry for the known object. In this situation, in order to overcome the deficit a new entry must be created.

It is proposed, here, that in order to perform an object's function, the subject must first know the object as an unknown object. In so doing, the other features of the object may be attended to and become salient for the new function. Developmentally, unknown objects are transformed into known objects through experience with them and their functions. In this case, it is suggested that to overcome functional fixedness the usual developmental process needs to be reversed.

6.6. Directions For Further Research:

The current studies suggest an almost endless array of areas to be explored for further clarification of the phenomena related to the acquisition of information from pictures. The main categories for related studies are in (1) the psychophysical aspects of picture perception, (2) the semantic and encyclopedic knowledge available from pictures, and (3) the cognitive processes involved in the extraction of functional information from pictures. Suggestions for the pursuit of each of these categories of investigation will be the final section discussed, but by no means the final discussion of the complex topic of the relationship between objects and their functions.

6.6.1. Psychophysical Aspects of Picture Perception: A careful and precise investigation of picture scanning needs to be conducted similar to the studies of Rayner (1975) and McConkie (1976) to determine more precisely the size of the perceptual window, the role of peripheral vision, and the relationship between the point of fixation and the attention of the subject. These studies could not be conducted with the experimental apparatus used in this study. They require instrumentation that is capable of more frequent sampling of the fixation location and finer discrimination to determine it.

6.6.2. Investigations of Semantic and Encyclopedic Knowledge: determine the role of specific defining features and to ascertain if these

features are searched for in assigning an identity to an object, a study could be conducted to investigate the sequence of fixation positions. Again, the orientation of the object could be varied but the subject would be required to state whether the object presented was one previously seen or a new one. To insure that the objects are scanned in a more careful manner and that fixations can be assigned to specific areas, the picture can be degraded to partially obscure the object. An alternative approach would be to vary the orientation of the object so that different features are obscured in successive presentations, either occluded by other objects or with the specific feature shown in an atypical perspective.

A set of studies that investigates how canonical orientation is assigned to objects would provide insight into this aspect of semantic knowledge. These studies are already under investigation in our laboratory. Stimuli are being selected according to several attributes. Some of the aspects to be investigated are (1) differences in assignment of canonical orientation for known and unknown objects, (2) differences in attributes of objects with canonical orientations and those without, (3) the influence of factors like size, apparent gravitational stability, and perspective on assigning canonical orientation to unknown objects and (4) the assignment of functions to unknown objects and the relationship of the functional position and the canonical position.

6.6.3. Cognitive Processes Involved in the Extraction of Functional Information from Pictures: Studies on the extraction of functional information from pictures could investigate and identify processing stages when making functional use decisions. It has been suggested that this is either a one or two stage process depending on whether the object is a known object or an unknown object. It needs to be tested with a larger set of objects and, especially, with more unknown objects. In addition, the stages for the two sets

of objects could be examined to determine if the stage in which the verification of function is the same in each case. It has been suggested that it is not since differing lengths of time are required.

A final area for further investigation is related to functional fixedness. It has been suggested that functional fixedness occurs when an object has a known identity from past experience. The research suggested here would be to determine if it is possible to cause a subject to treat a known object as an unknown object, either by obscuring defining features or degrading the picture, and to check for shifts in the processing steps that such a change might be expected to make. An alternative way to approach this study would be to provide several semantic labels for an unknown object and determine if different features are selected as defining features as subjects become familiar with the object.

While these future studies illustrate how many questions remain unanswered; the studies presented here suggest, in their own right, patterns of how functional and canonical information are related in picture and text processing.

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Table 1. The functional uses selected for each of the five objects in three different orientations.

OBJECT	0 DEGREES	90 DEGREES	180 DEGREES
flower pot	hold nickles	wheel for toy car	cookie cutter
mitten	golf club cover	bed for a mouse	hold tardsies
paring knife	spindle bills	scrape paint	stir coffee
wooden wedge	spread jelly	level a table	prop open a window

Table 3. Mean canonical and functional goodness ratings for the eight orientations of the flower pot based on an N of 25.

DEGREES CLOCKWISE ROTATION	CANONICAL RATING	FUNCTIONAL RATING		
		hold nickles	wheel	cookie cutter
0	1.0	1.5	6.8	3.0
45	5.5	2.6	5.8	5.7
90	5.1	4.3	2.3	6.1
135	6.4	6.6	5.6	5.8
180	3.9	6.4	6.4	2.0
225	6.3	6.4	5.9	5.8
270	5.0	5.0	2.4	6.0
315	6.4	3.3	5.6	5.6

Table 4. Mean canonical and functional goodness ratings for the eight orientations of the knife based on an N of 25.

DEGREES CLOCKWISE ROTATION	CANONICAL RATING	FUNCTIONAL RATING		
		spiral bind	square point	stir coffee
0	3.4	1.9	3.5	1.7
45	3.3	4.2	3.0	4.1
90	2.4	4.7	2.8	6.2
135	3.6	5.0	2.5	3.6
180	3.2	2.7	4.5	1.6
225	5.0	5.2	4.2	3.8
270	4.3	4.5	4.1	6.6
315	4.7	4.3	3.5	4.5

Table 6. Mean canonical and functional goodness ratings for the eight orientations of the cup based on an N of 25.

DEGREES CLOCKWISE ROTATION	CANONICAL RATING	FUNCTIONAL RATING		
		hold vinegar	scoop sand	cricket trap
0	1.0	1.0	5.8	4.7
45	4.6	3.2	4.5	5.5
90	5.8	6.0	3.5	5.2
135	5.2	6.6	3.6	4.4
180	2.4	6.7	5.7	2.0
225	4.5	6.7	2.8	4.2
270	4.4	5.7	5.1	4.4
315	3.8	3.0	4.0	5.1

Table 7. Mean canonical and functional goodness ratings for the eight orientations of the mitten based on an N of 25.

DEGREES CLOCKWISE ROTATION	CANONICAL RATING	FUNCTIONAL RATING		
		hold egg color	soak tea	hold handing
0	2.3	1.1	4.3	6.3
45	3.1	3.9	3.9	5.0
90	2.4	5.2	1.7	2.8
135	4.1	5.8	4.4	3.0
180	2.9	6.0	4.3	3.0
225	4.2	5.6	4.2	3.2
270	3.1	5.0	1.6	3.0
315	3.8	3.3	4.3	4.2

Table 8. Mean canonical and functional goodness ratings for the eight orientations of the wedge based on an N of 25.

DEGREES CLOCKWISE ROTATION	CANONICAL RATING	FUNCTIONAL RATING		
		spread jelly	level table	press window
0	3.0	3.4	6.0	2.8
45	4.2	2.1	5.5	3.7
90	1.8	2.8	1.1	3.5
135	5.6	4.4	6.0	4.0
180	4.7	4.3	6.1	2.8
225	5.7	4.6	6.2	4.0
270	2.6	3.2	1.5	3.9
315	4.2	2.7	5.7	3.7

Table 7. Mean length (in centimeters) in the different areas of the five objects studied. The data are given in centimeters. Each tick is 1/10 of a centimeter.

OBJECT	AREA	MEAN	STDEV
flower pot (n=40)	rim	19.1	23.7
	base	19.2	21.4
	total	37.3	40.5
mitten (n=40)	hand	12.1	14.7
	thumb	11.7	20.1
	cuff	7.4	19.7
	total	35.7	31.5
knife (n=40)	tip	6.5	10.7
	blade	17.1	21.0
	handle	17.4	17.7
	total	39.7	39.4
wedge (n=40)	base	27.4	37.1
	band	11.7	14.7
	tip	15.1	21.1
	total	50.2	44.5
cup (n=40)	rim	12.4	21.1
	base	14.4	20.0
	handle	17.4	30.4
	total	44.2	54.5

Table 9. Correlation for the areas of the mitten with the canonical and functional scales. The correlation coefficient and probability are given for each area. (Significance *.05, **.01, ***.001)

USE	AREA	CORRELATION AND PROBABILITY WITH FUNCTIONAL SCALE	CORRELATION AND PROBABILITY WITH CANONICAL SCALE
ALL USES (N=40)	hand	-.205* .035	.127 .200
	thumb	.235 .057	.070 .323
	cuff	.158 .147	.181 .114
GOLF CLUB COVER (N=16)	hand	-.856*** .000	.253 .177
	thumb	.115 .330	-.077 .396
	cuff	.214 .213	.251 .173
MOUSE BED (N=14)	hand	.130 .329	.002 .377
	thumb	.245 .199	.093 .376
	cuff	.117 .346	.354 .107
HOLD MARBLES (N=16)	hand	.075 .391	.010 .485
	thumb	.341 .098	.262 .163
	cuff	-.154 .285	.214 .197

Table 10. Correlation for the areas of the mitten with the canonical and functional scales. The correlation coefficient and probability are given for each area. (Significance *.05, **.01, ***.001)

USE	AREA	CORRELATION WITH FUNCTIONAL SCALE	CORRELATION WITH CANONICAL SCALE
ALL USES (N=40)	hand	-.17 .03	-.17 .03
	base	-.17 .03	.17 .03
HOLD MARBLES (N=16)	hand	-.17 .03	-.17 .03
	base	.17 .03	.17 .03
WHEEL (N=14)	hand	.17 .03	-.17 .03
	base	-.17 .03	.17 .03
CUPPING BUTTER (N=14)	hand	-.17 .03	-.17 .03
	base	-.17 .03	.17 .03

Table 11. Correlation for the areas of the mitten with the canonical and functional scales. The correlation coefficient and probability are given for each area. (Significance *.05, **.01, ***.001)

USE	AREA	CORRELATION WITH FUNCTIONAL SCALE	CORRELATION WITH CANONICAL SCALE
ALL USES (N=40)	handle	.17 .03	.17 .03
	blade	-.17 .03	-.17 .03
	tip	-.17 .03	-.17 .03
SPINDEL WHEEL (N=14)	handle	-.17 .03	.17 .03
	blade	-.17 .03	.17 .03
	tip	-.17 .03	-.17 .03
SCRAPPY FAINT (N=14)	handle	.17 .03	.17 .03
	blade	.17 .03	-.17 .03
	tip	-.17 .03	-.17 .03
STIR COFFEE (N=16)	handle	-.17 .03	.17 .03
	blade	-.17 .03	-.17 .03
	tip	-.17 .03	-.17 .03

Table 11. First four partial correlations of the areas of the body parts of the cricket with the probability of being caught by the hand. The first four partial correlations are given for each area. The last four partial correlations are given for the areas of the body parts of the cricket.

USE	AREA	CORRELATION WITH PROBABILITY WITH FUNCTIONAL SCALE	CORRELATION WITH PROBABILITY WITH CANONICAL SCALE
ALL USED (N=41)	base	.100 .210	.100 .200
	bend	.121* .024	.104 .301
	tip	.111 .108	.107 .300
HOLD VISION (N=11)	base	.100 .100	.100 .100
	bend	-.117 .093	-.110 .110
	tip	-.010 .400	.000 .400
LEVEL TABLE (N=15)	base	-.117 .310	-.053 .400
	bend	.495* .030	.263 .127
	tip	.284 .153	.100 .360
PROP WINDOW (N=15)	base	.400 .010	-.075 .117
	bend	-.115 .310	.251 .183
	tip	-.113 .344	.203 .234

Table 12. First four partial correlations of the areas of the body parts of the cricket with the probability of being caught by the hand. The first four partial correlations are given for each area. The last four partial correlations are given for the areas of the body parts of the cricket.

USE	AREA	CORRELATION WITH PROBABILITY WITH FUNCTIONAL SCALE	CORRELATION WITH PROBABILITY WITH CANONICAL SCALE
ALL USED (N=41)	handle	.100 .343	.100 .343
	rim	-.115 .140	-.107 .140
	base	-.003 .140	-.004 .140
HOLD VISION (N=11)	handle	.100 .111	.100 .100
	rim	-.003 .394	.100 .273
	base	.503* .007	.653** .000
SCOOT DAND (N=15)	handle	-.000 .203	.198 .249
	rim	-.463* .040	.110 .354
	base	.019 .475	.160 .203
TRAP CRICKET	handle	.100 .490	.100 .120
	rim	-.000 .497	-.000 .100
	base	-.003 .157	-.000 .000



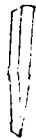
cup



mitten



knife



wedge



cup

Figure 1. Line drawings of the five objects used in the examination of functional uses of objects. All objects are presented in their assigned 0 degree orientation.

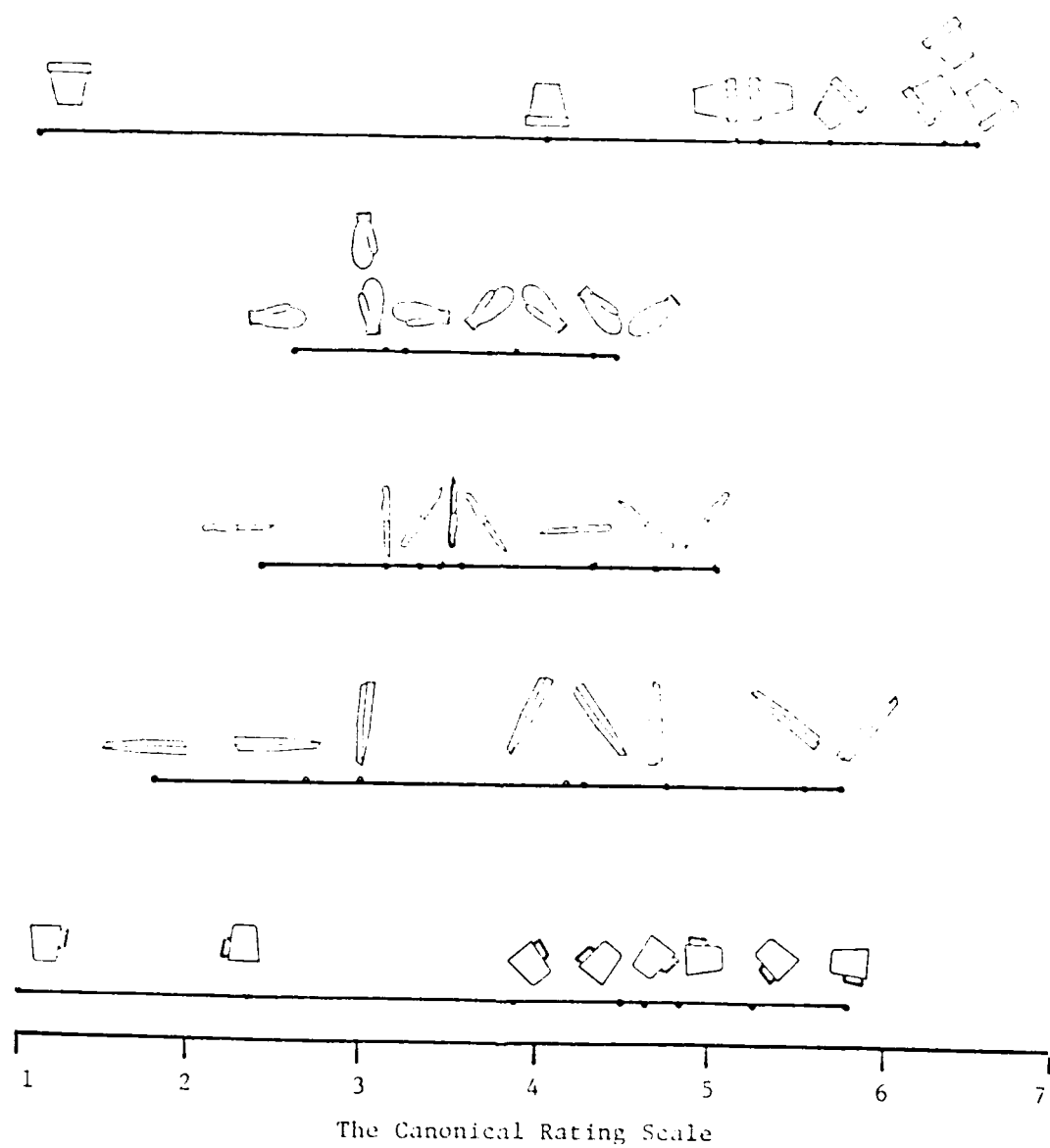


Figure 2. The canonical rating scales developed for the five objects studied.

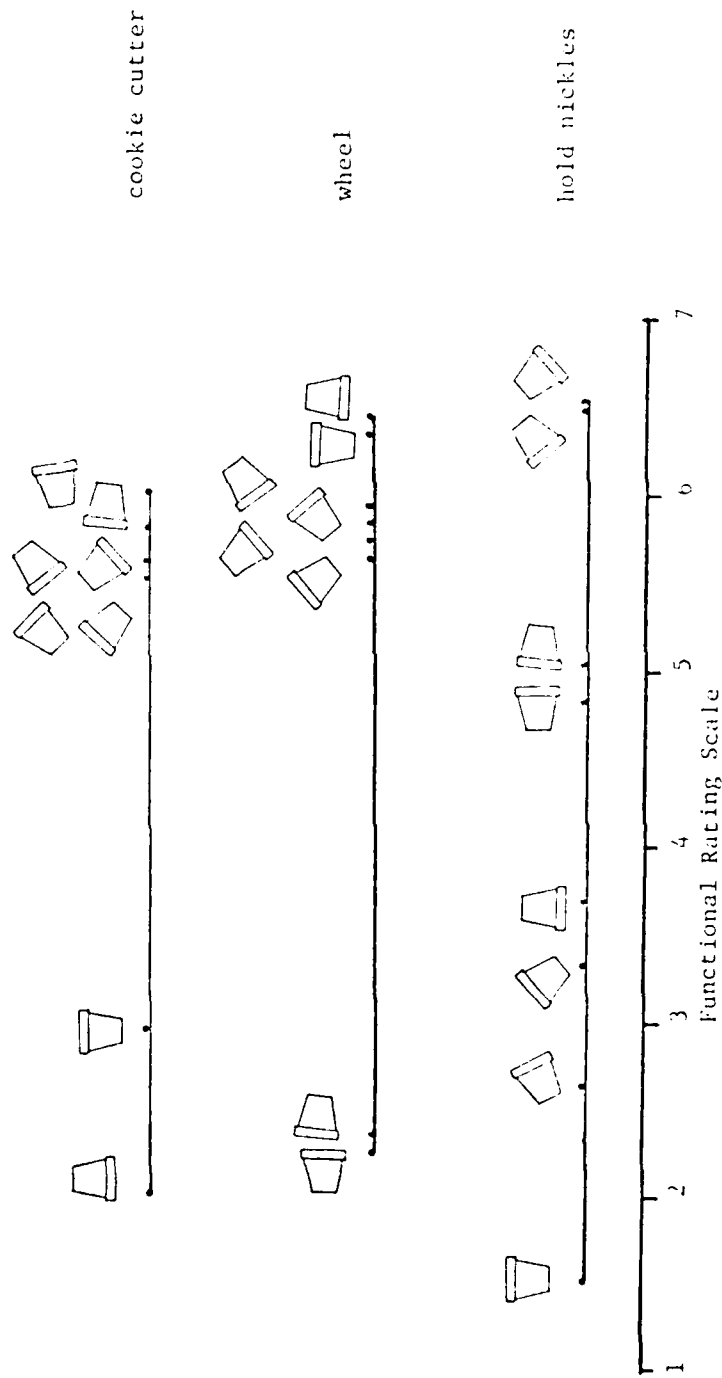


Figure 3. The functional rating scales for the flower pot.

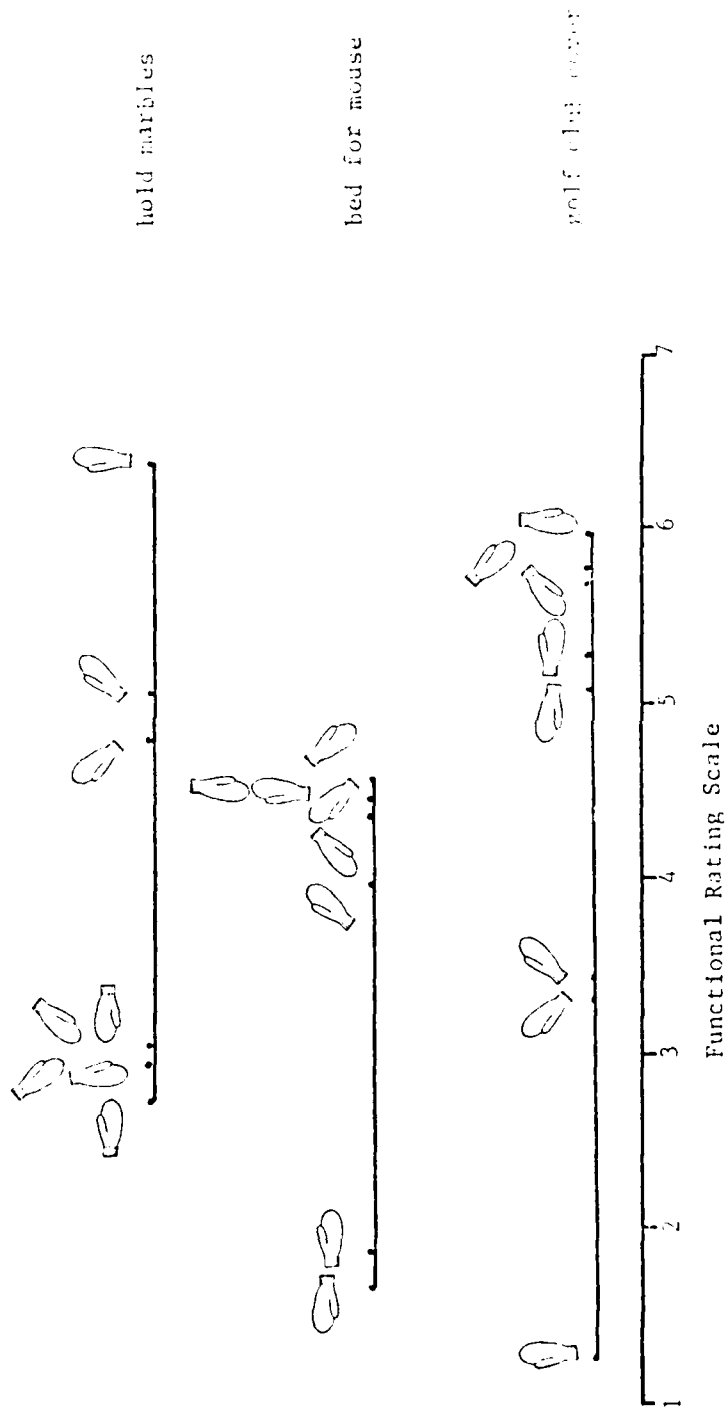
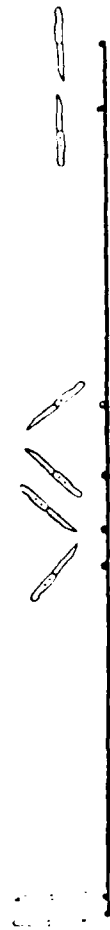
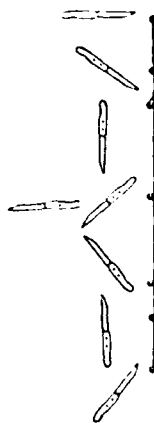


Figure 4. The functional rating scales for the mitten.



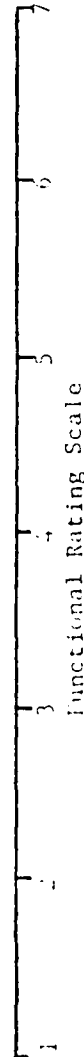
for stirring coffee



scraping paint



spindle bills



Functional Rating Scale

Figure 1. Functional rating scales for the Parula.

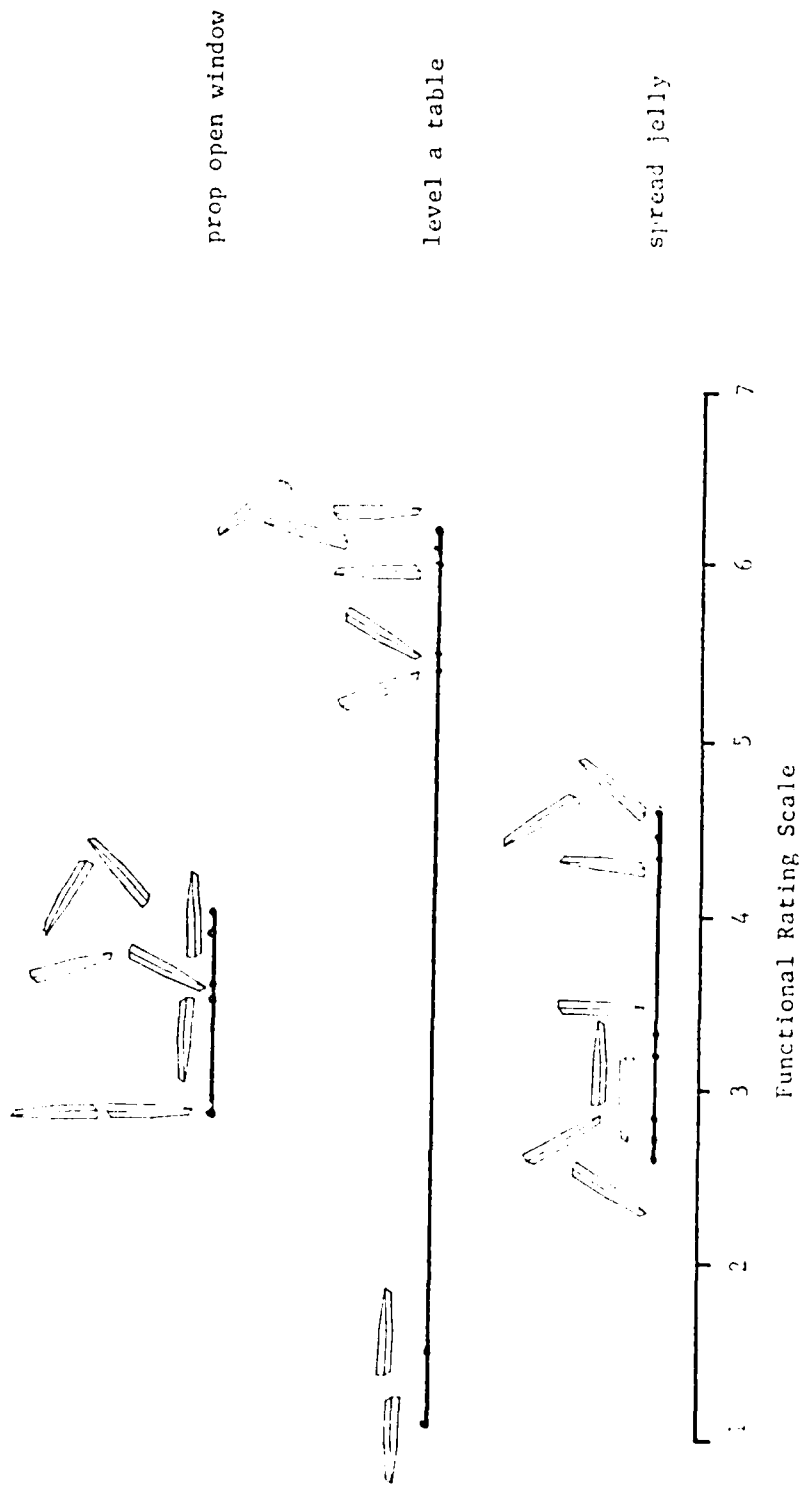


Figure 6. The functional rating scales for the wedge.

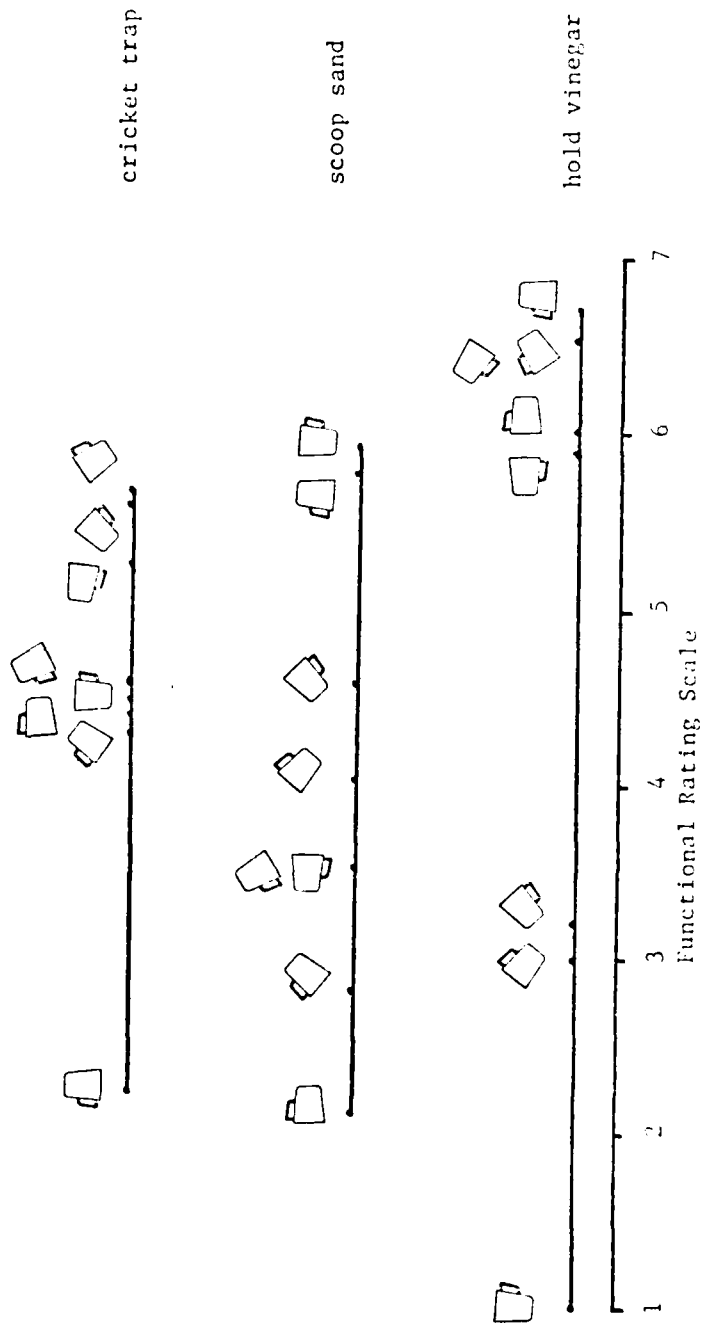


Figure 7. The functional rating scales for the cup.

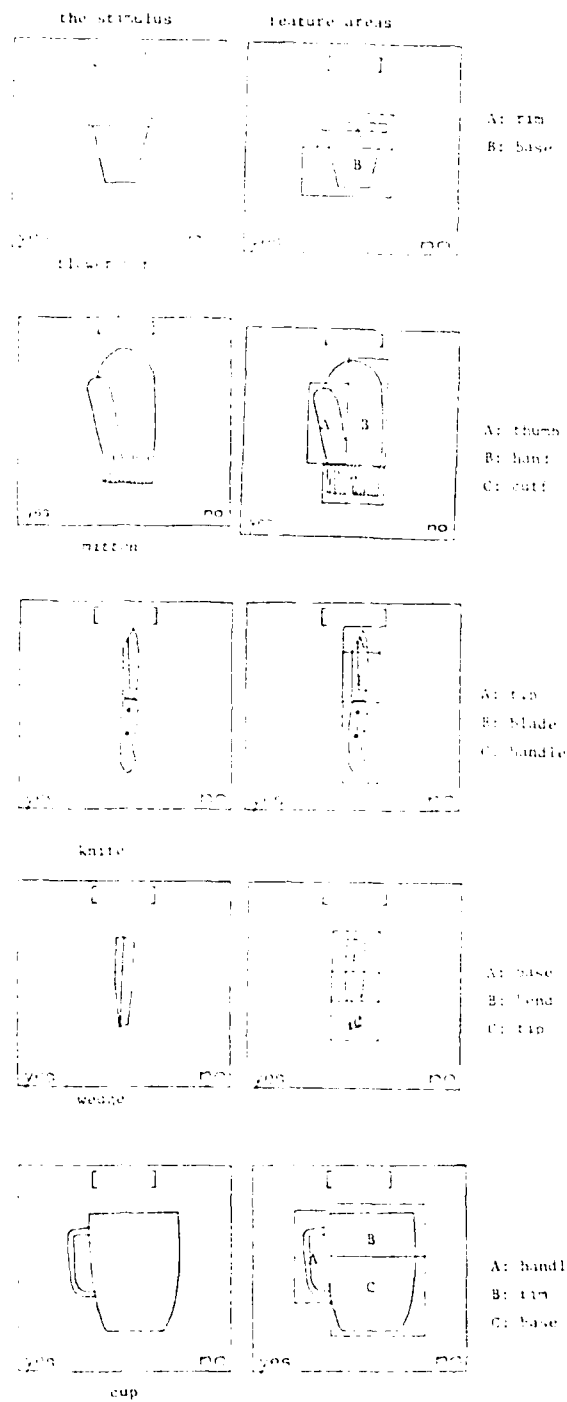


Figure 3. The stimuli for the eye trace experiment and the feature areas into which they are divided.

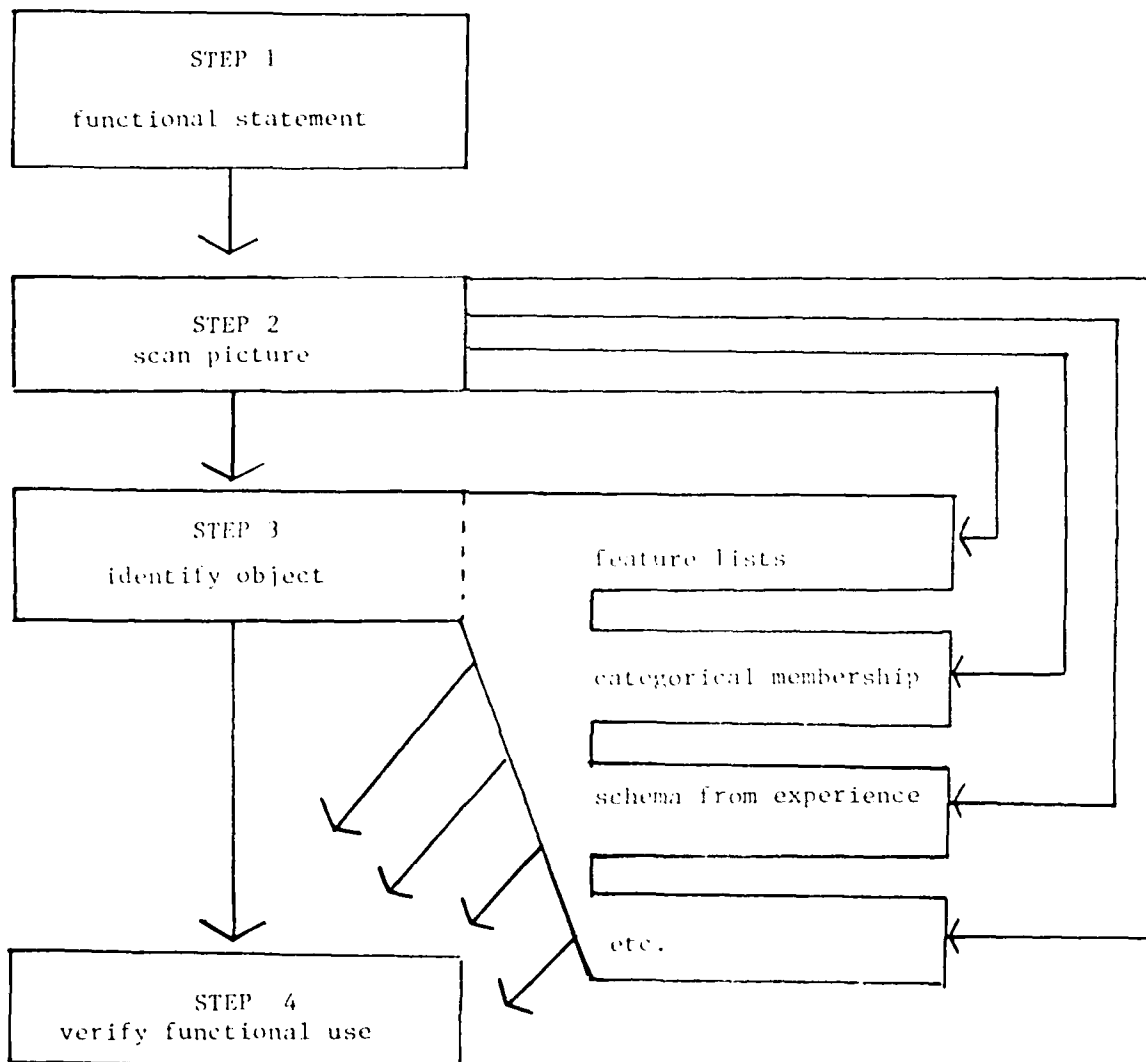


Figure 9. A model of the processes necessary for decision making regarding functional uses of common objects.

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